Comparing Smart Cities with Different Modeling Approaches

Leonidas Anthopoulos
Associate Professor
Business School, TEI of Thessaly
41110 Larissa, Greece
+302410684570
lanthopo@teilar.gr

Marijn Janssen
Professor
Delft University of Technology,
The Netherlands
M.F.W.H.A.Janssen@tudelft.nl

Vishanth Weerakkody
Professor, Brunel Business School,
Brunel University London Uxbridge,
United Kingdom
vishanth.weerakkody@brunel.ac.uk

ABSTRACT
Smart cities have attracted an extensive and increasing interest from both science and industry with an increasing number of international examples emerging from across the world. However, despite the significant role that smart cities can play to deal with recent urban challenges, the concept has been criticized for being influenced by vendor hype. There are various attempts to conceptualize smart cities and various benchmarking methods have been developed to evaluate their impact. In this paper the modelling and benchmarking approaches are systematically compared. There are six common dimensions among the approaches, namely people, government, economy, mobility, environment and living. This paper utilizes existing smart city analysis models in order to review three representative smart city cases and useful outcomes are extrapolated from this comparison.

Categories and Subject Descriptors
C.4.3 [**Measurement Techniques**]: Computer Systems Organization - *Performance of Systems – abstract data types, polymorphism, control structures.*

General Terms
Measurement, Documentation, Performance.

Keywords
Smart city; performance measurement; modeling.

1. INTRODUCTION
Smart cities have been defined in various ways by different scholars [1; 2; 3; 4; 5; 6; 7]. Smart cities have lately not been limited to information and communication technologies (ICT), but and are focused on enhancing urban life regarding six dimensions: people, government, economy, mobility, environment and living [8]. Angelidou [9] approached smart city using a civil engineering and urban architecture lens and classified smart cities as new versus existing cities, and corresponding smart city projects to "soft" versus "hard" implementations. More than 150 smart city cases can be observed around the world, which can be classified in (a) from-scratch city cases; (b) hard ICT infrastructure focused cases; and (c) soft ICT infrastructures in the urban space. Since there is no clear smart city approach yet, there have been several attempts by international organizations to standardize smart city solutions, such as for smart water, energy, transportation, buildings etc.

Recently scholars have started criticizing the use of smart city concept and potential [see for example 10, 11, 12]. Some scholars argue that smart city is mostly the outcome of vendors' marketing campaigns [10], others say that smart cities reflect little more than usual urban innovations [11], while Brown [12] criticizes the whole concept of smart city by questioning their effectiveness.

To shed light on the smart cities concepts, various models for understanding and conceptualizing smart cities have been developed, which aim to define their scope, objectives and architectures. Also benchmarking methods for comparing smart cities initiatives with each other have been developed. The aim of this paper is to analyze the existing smart city modeling and benchmarking methods. Such a presentation is of extreme interest to the smart city domain, due to the continuous public spending in this domain, for which no agreed framework has been defined to evaluate the achievements regarding the initially grounded expectations.

The remainder of this paper is structured as follows: section 2 provides an overview of the research approach, followed by an analysis of existing smart city modeling and benchmarking approaches and concluding with a brief discussion on the most appropriate to apply for the purposes of this paper. The following section discusses findings, while section 5 contains some conclusions and future thoughts.

2. RESEARCH APPROACH
An analysis was performed with literature review, with findings from the following sources: international standards organizations for smart city documents; and SCOPUS, with searches only in journals that publish smart city articles [8], with the combination of terms "smart city", "model" and "assessment". Article crawl was performed within the period of 1997 (appearance of smart city concepts in literature) to early 2015. More than 200 articles were returned from this crawl, where screening was used to leave out irrelevant publications (like "urban growth assessment").

WWW 2015 Companion, May 18–22, 2015, Florence, Italy.
ACM 978-1-4503-3473-0/15/05
http://dx.doi.org/10.1145/2740908.2743911

3. FINDINGS

3.1 Smart cities models

Various organizations and scholars have approached smart city with different models (Table 1). IBM [10] uses a nine pillar system and an equation that combines instrumentation, interconnection and intelligence. The International Telecommunications Union [13] defined key-performance indicators for smart sustainable cities, which align to United Nations Habitat [14] dimensions for city prosperity. Anthopoulos [8] compared eight (8) models and concluded to a seven-axe modeling tool, which confirms the above 6 dimensions of smart city and extends them with *coherency* in terms of social equity and engagement. International Standards Organization [15] proposed a standard for city services and quality of life, as a means to measure smart city sustainable development. Neirotti et al. [1] extend the 6 dimensions of smart city modeling with the incorporation of *smart building*. Finally, Lee et al. [5] presented a framework for smart city analysis, which focuses on the dimention of integration for urban growth.

The overview of the models show the heterogeneity of the smart cities concept. Some of the models have hardly any overlapping factors, whereas the ISO models capture a large number of aspects. The broadness of these aspects results to the unclarity of the concept. Yet there are 6 dimensions that are part of most models; people, government, economy, mobility, environment and living.

Table 1. Smart city modeling approaches

	Model	Description
IBM [10]	Nine Pillar Models Smarter City Equation	Planning and Management Services Infrastructure Services Human Services Instrumentation (*the transformation of urban phenomena into data*) + Interconnection (*of data*) + Intelligence (*brought by software*)
ITU [13]	Smart Sustainable City Key Performance Indicators	Environmental Sustainability, Productivity, Quality of Life, Equity and Social Inclusion, Infrastructure development
UN Habitat [14]	Dimensions of City Prosperity	Productivity and the Prosperity of Cities, Urban Infrastructure: Bedrock of Prosperity, Quality of Life and Urban Prosperity, Equity and the Prosperity of Cities, Environmental Sustainability and the Prosperity of Cities
Anthopoulos [7]	Smart city dimensions	Resource, Transportation, Urban infrastructure, Living, Government, Economy, Coherency
ISO [15]	ISO 37120 Sustainable development of Communities Indicators for city services and quality of life	Economy, Education, Energy, Environment, Finance, Fire and Emergency Response, Governance, Health, Recreation, Safety, Shelter, Solid Waste, Telecommunication and Innovation, Transportation, Urban Planning, Waste water, water and sanitation
Neirotti et al. [1]	Smart City domains	Natural resources and energy, Transport and mobility, Buildings, Living, Government, Economy and people
Lee et al. [5]	Framework for smart city analysis	Urban Openness, Service Innovation, Partnerships Formation, Urban Proactiveness, Smart city infrastructure integration, Smart city governance

3.2 Smart cities benchmarking methods

Benchmarking has the purpose to compare smart cities with each other based on various constructs and factors. Table 2 provides an overview of benchmarking methods aimed at measuring smart cities from different perspectives, such as sustainability [16]; global city performance [17]; resilience [3]; local government effectiveness [18]; urban competitiveness [19]; and good urban governance [19]. With regard to the 6 dimensions of smart city, only [21] defined a model with corresponding indices in an attempt to assess urban intelligence. Finally, [22] focus on a specific smart city class (the Digital City) and defined an assessment framework for ICT efficiency (connectivity, accessibility and communicability).

Given the broadness of this field it is not surprisingly that there are many benchmarking approaches developed. In a similar vein to the modelling overview, the benchmarking comparisons also show the diversity of dimensions that are taken into account. The benchmarks look sometimes at completely different aspects which hampers comparison. This makes it hard or even impossible to compare the benchmarking outcomes with each other. In one benchmark, a city might be doing well, whereas the same city might be performing lower in another benchmark. In general, with the exception of 21, it appears that scholars do not follow exiting modeling when they introduce their benchmarking methods.

Table 2. Smart city benchmarking tools

	Benchmarking Tool	Description
Pires et al. [15]	Local Sustainable Development Indicators	21 ECOXXI Indicators, grouped in the following sectors: Sustainable, Development Education, Marine and Coastal Environment Institutions, Nature Conservation and Biodiversity, Forest Planning, Air, Water, Waste, Energy, Transport, Noise, Agriculture, Tourism
Kourtit et al. [16]	Global City Performance Measurement Indexes	Economy, Research and Development, Cultural Interaction, Livability, Environment, Accessibility
Desouza and Flanery [3]	Resilience City Evaluation and Implementation Framework	City components: Resources and Processes (Physical) People, Institutions, Activities (Social)
da Cruz and Marques [17]	Sustainable Local Government Scorecard	Social, Economic, Environmental and Government *criteria*
Singhal et al. [18]	Competitiveness parameters	Physical Environment, Social Capital, Finance, Development, Investment, User Potential
UN Habitat [19]	Good Urban Governance indicators	Effectiveness, Equity, Participation, Accountability, Security
Lazaroiu et al. [20]	Model for computing "the smart city" indices	Economy, Mobility, Environment, People, Living, Governance
Duarte et al. [21]	Digital City Assessment Framework	Connectivity, Accessibility, and Communicability

4. DISCUSSION

In recent years, there have been many approaches to benchmark smart cities. Our literature findings show that the UK [23] and the US National Institute of Standards and Technology [24] are in the process of defining smart city and corresponding Internet-of-Things standards respectively, while an international effort is also underway on standardizing smart city and corresponding solutions. Existing standards mainly focus on urban sustainability and resilience, which demonstrate that smart city efforts are, or will be placed mainly on these directions. The smart city context is close to a secure definition, since the 6 dimensions (people, governance, mobility, economy, environment and living) that are recognized for enhancement, are agreed by all scholars, even with small variations. However, most scholars have limited their analysis of the smart city context to an urban innovation.

On the other hand, researchers have tried to evaluate smart city from different lens: sustainability and resilience; city performance and competitiveness; and urban governance are different approaches, which measure the impact of innovation in urban daily processes. Only 2 works [21; 22] try to evaluate ICT and smart solutions directly, which leave a space for future research.

5. CONCLUSIONS

This paper explored existing smart city modeling and benchmarking methods. A systematic overview of the main components was created. The overview confirmed the diversity of factors taken into account and different views that can be taken. To this end, the paper focused on models and assessment frameworks, which are either still being development by prestigious organizations or are being tested by scholars.

The smart city field is close to a uniform definition, which deals with innovation (not necessarily ICT-based) in the urban space. This is a very broad definition to cover the many and variety of initiatives in this field. As such smart cities are an umbrella term for all sorts of innovations in the urban environment.

Moreover, standards –such as the ones introduced by [23; 24]- are under development for smart cities and corresponding solution definitions, which illustrate that vendors and organizations with commercial vested interest may aim to define this evolving market. With regard to smart city assessment, scholars mainly evaluate the impact of innovation on urban performance, rather than the direct smart solution or architecture. Both these findings show that the smart city domain is still embryonic and promises important future results for governments, academia and industry. As future research, we recommend developing a taxonomy of smart cities to deal with the variety and to use this taxonomy to position modelling and benchmarking efforts.

6. REFERENCES

[1] P. Neirotti, A. De Marco, A.C. Cagliano, G. Mangano, and F. Scorrano, "Current trends in Smart City initiatives: Some stylised facts," *Cities*, (38), 25-36, 2014.

[2] G. Piro, I. Cianci, L.A. Grieco, G. Boggia, and P. Camarda, "Information centric services in smart cities", *The Journal of Systems and Software*, 88, pp. 169-188, 2014.

[3] K.C. Desouza, and T.H. Flanery, "Designing, planning, and managing resilient cities: A conceptual framework," *Cities*, 35, pp. 88-89, 2014.

[4] W.-M. Wey, and J. Hsu, "New Urbanism and Smart Growth: Toward achieving a smart National Taipei University District," *Habitat International*, 42, pp. 164-174, 2014.

[5] J.H. Lee, M.G. Hancock, and M-C Hu, "Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco," *Technological Forecasting & Social Change*, 2013 http://dx.doi.org/10.1016/j.techfore.2013.08.033

[6] R. Giffinger, C. Fertner, H. Kramar, E. Meijers and N. Pichler-Milanovic, "Smart Cities: Ranking of European medium-sized cities," 2007 [Online]. Available: http://www.smart-cities.eu/download/smart_cities_final_report.pdf

[7] H. Chourabi, N. Taewoo, S. Walker, J.R. Gil-Garcia, S. Mellouli, K. Nahon, T.A. Pardo, and H.J. and Scholl, "Understanding Smart Cities: An Integrative Framework". In *45th Hawaii International Conference on System Science (HICSS)*, pp. 2289-2297, 2012.

[8] L. Anthopoulos, "Understanding the smart city Domain: A Literature Review," in Bolivar M.P. (Ed) *Transforming City Governments for successful Smart Cities*, Public Administration and Information Technology Series, Vol. 3, Springer Science+Business Media New York, Forthcoming.

[9] M. Angelidou, "Smart city policies: A spatial approach," *Cities*, 41, S3-S11, 2014.

[10] O. Söderström, T. Paasche, and F. Klauser, "Smart cities as corporate storytelling", *City*: analysis of urban trends, culture, theory, policy, action, 18:3, 307-320, 2014, DOI: 10.1080/13604813.2014.906716.

[11] T. Nam, and T. Pardo, "Smart city as urban innovation: Focusing on management, policy, and context," *5th international conference on theory and practice of electronic governance*, 26–28 September 2011, Tallinn, Estonia.

[12] L.A. Brown, "The city in 2050: A kaleidoscopic perspective", *Applied Geography*, 49, pp. 4-11, 2014.

[13] International Telecommunications Union (ITU), "Overview of key performance indicators in smart sustainable cities," 2014 [Online]. Available: http://www.itu.int/en/ITU-T/focusgroups/ssc/Pages/default.aspx

[14] United Nations (UN), "State of the World's Cities 2012/2013," 2014 [Online]. Available: http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3387

[15] International Standards Organization (ISO), "*ISO 37120:2014 - Sustainable development of communities -- Indicators for city services and quality of life*," 2014.

[16] M. Pires, T. Fidelis, and T.B. Ramos, "Measuring and comparing local sustainable development through common indicators: Constraints and achievements in practice," *Cities*, 39, pp. 1-9, 2014.

[17] K. Kourtit, C. Macharis, and P. Nijkamp, "A multi-actor multi-criteria analysis of the performance of global cities," *Applied Geography*, 49, pp. 24-36, 2014

[18] N.F. da Cruz, and R.C. Marques, "Scorecards for sustainable local governments," *Cities*, 39, pp. 165-170, 2014.

[19] S. Singhal, S. McGreal, and J. Berry, "Application of a hierarchical model for city competitiveness in cities of India," Cities, 31, pp. 114-122, 2013.

[20] United Nations (UN) Habitat, "Urban Governance Index (UGI): A tool to measure progress in achieving good urban governance," 2014 [Online]. Available: http://ww2.unhabitat.org/campaigns/governance/documents/UGIndex%205%20pager.pdf

[21] G.C. Lazaroiu, and M. Roscia, "Definition methodology for the smart cities model," *Energy*, 47, pp. 326-332, 2012.

[22] F. Duarte, F. de Carvalho Figueiredo, L. Leite, and D.A. Rezende, "A Conceptual Framework for Assessing Digital Cities and the Brazilian Index of Digital Cities: Analysis of Curitiba, the First-Ranked City," *Journal of Urban Technology*, 21:3, 37-48, 2014 DOI: 10.1080/10630732.2014.940709

[23] British Standards Institute, "PAS 180 Smart city terminology," 2014 [Online]. Available: http://www.bsigroup.com/smart-cities/Smart-Cities-Standards-and-Publication/PAS-180-smart-cities-terminology/

[24] National Institute of Standards and Technology, "Global City Teams Challenge Kick-off," [Online]. Available: http://www.nist.gov/cps/global-city-teams-challenge-workshop.cfm